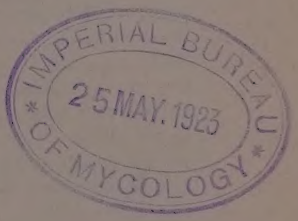
1923

Bulletin 186 February, 1923

Potato Diseases in Nebraska

R. W. GOSS

DEPARTMENT OF PLANT PATHOLOGY



THE UNIVERSITY OF NEBRASKA
COLLEGE OF AGRICULTURE
EXPERIMENT STATION
LINCOLN

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POTATO DISEASES IN NEBRASKA

R. W. GOSS

DEPARTMENT OF PLANT PATHOLOGY

The potato growers of Nebraska must take increasingly greater precautions against the introduction and spread of potato diseases as the industry in the State increases. Unless this is done it will be found that while the acreage is increasing the yields are gradually diminishing. It is a well-known fact that the number and severity of the diseases will increase in proportion to the length of time the crop is grown in a given locality.

Many potato diseases are carried in or on the seed tubers and as seed is brought in from other sections the diseases of those regions are introduced into the State. These diseases once established in the soil are increased yearly with repeated plantings of potatoes. Furthermore, in the newer potato growing sections, many of the growers are not familiar with the various diseases and so they may become well established in their fields before their severity is recognized.

The establishment by the College of Agriculture of rules for inspection and certification of seed potatoes, and the operation of the state potato grading law, have emphasized the necessity for disease-free potatoes for both seed and table use. This has resulted in an increased demand from the growers for information relative to these diseases.

It was with the purpose of supplying the potato growers of the State with information regarding the recognition and control of the various diseases of the potato that this bulletin was prepared.

Owing to lack of space, many details are omitted in this publication. Several diseases present in the United States but not as yet reported from Nebraska are not described. Growers are urged to write to the Department of Plant Pathology, Agricultural College, Lincoln, for further information or for the identification of diseases of the potato or other crops. Specimens should be sent in if identification is wanted, and this is especially desirable if diseases are observed that do not closely correspond to the descriptions in this bulletin.

POTATO GROWING SECTIONS OF THE STATE AND THEIR CHIEF DISEASES

While many of the diseases listed in this bulletin are common to all sections of Nebraska, their severity varies in different sections of the State, due to the environmental conditions under which the crop is grown. The relative importance of certain diseases also depends to some extent upon the purposes for which the crop is being grown, which is again dependent upon the environmental conditions, chiefly temperature, moisture, and soil.

The potato thrives best in a fairly cool climate. The plants lose their vigor and the tubers are not suitable for seed purposes when grown in very hot sections. Thus we find the chief potato seed producing states along the northern border of the United States. Upon these sections the southern states depend for their seed potatoes.

Nebraska differs from many other states in that, while good seed potatoes can be produced in some sections, there are other sections in which potatoes are grown only for the table market and are unfit for seed purposes. This is due to the wide variation in rainfall from about 30 inches annual precipitation in the east to 16 inches in the western part of the State, and to temperature differences which range from an average of 72° to 74° in the southeastern part of the State to 66° F. in the western part for the period between June 1 to September 30. The different methods of culture used in the irrigated and dry land sections of the western part of the State also determine the value of the crop for seed purposes.

From the disease standpoint the potato industry of Nebraska may be divided into four sections:

1. *Eastern Nebraska Section*—In this area early potatoes are grown chiefly for the local markets. Due to high temperatures potato growing in this section is in some ways comparable with that in the southern states. The tubers will not produce vigorous plants and retain their high productiveness if grown continually in this section. Because of this, seed potatoes have been purchased chiefly from outside sources, and a rather high percentage of disease has been introduced. Under the temperature and moisture conditions of this section certain diseases are particularly abundant. The organisms causing scab, Rhizoctonia, and Fusarium wilt

are present in considerable quantities in most of the soils and are also introduced with much of the new seed, provided uncertified seed is used. The severity of these diseases varies with the temperature and moisture conditions of the season, as will be discussed later. The chief diseases causing reductions in the yield in this section are the foliage diseases, tipburn and hopperburn, sometimes combined with early blight or mosaic. These foliage troubles are most severe during the hottest weather, and result in the premature dying of the tops with a corresponding decrease in yield.

2. *South Central Section*—In the region around Kearney and Grand Island a considerable acreage is devoted to the growing of early potatoes for the commercial markets. While the rainfall is not as great here as along the eastern border of the State, it is supplemented in many cases by pump irrigation. The diseases here are similar to those in eastern Nebraska, except that the foliage diseases are not quite so severe. Much of the seed is brought in from northern states where blackleg is prevalent, resulting in a considerable amount of this disease being present in the fields, particularly under irrigation.

3. *Western Irrigated Section*—Potatoes are grown under irrigation in the Kimball section but the greater quantity of irrigated potatoes are produced in the North Platte valley. It has been found that these potatoes are not generally suitable for seed purposes. While it would be possible to produce good seed potatoes on the lighter soils with a minimum of irrigation water, it is to the advantage of the grower to produce maximum yields for table use, rather than to reduce his yields in an effort to produce good seed potatoes. The heavier soils in this section with the abundance of water result in a condition very favorable for many diseases. Foliage diseases, such as tipburn and early blight, are not of any great importance, but severe damage often results from scab and Rhizoctonia. The use of irrigated seed of low vitality and imported seed with a high percentage of mosaic and Fusarium wilt causes the greatest reduction in yields. Excessive water or careless handling of the potatoes after digging often results in a large amount of tuber rots either in the field or in storage.

4. *Western Dry Land Section*—The potato industry in this part of the State has developed very rapidly during recent years. This has been due largely to the increased acreage being planted for the purpose of raising seed potatoes. The

elevation thruout the section, 3,000 to 5,000 feet, results in temperature conditions favorable for the production of vigorous seed. The growers who have been careful as to the source of their seed supply and who have handled their crop carefully have been able to produce a high quality of seed, comparatively free from disease. The severity of the diseases varies in different parts of this section. In general the most serious, because of its importance to the southern growers who buy seed from this section, is the mosaic disease. The Bliss Triumph variety is very susceptible to this disease. It is, however, grown thruout this area, with as small an amount of mosaic as anywhere else in the United States. This has been due chiefly to the freedom from disease of several strains of potatoes that have been widely planted thruout this region and to the scarcity of the insects that carry the disease from plant to plant. The relative isolation of the potato fields being grown for seed purposes in this section has also materially checked the spread of the disease from field to field. Except in cases of very severe infection, this disease does not appreciably reduce the yield in this area, but as will be pointed out, it is of the greatest importance to growers selling seed to the South.

In the southern part of this section, thru Kimball and Cheyenne Counties, mosaic is very hard to detect owing to the type of growth produced with the high temperature, low moisture, and intense sunlight conditions present in this area. Blackleg is very uncommon in this section, due to the low soil moisture content. Other diseases, such as scab and Rhizoctonia, are present to some extent.

Further north, thru Box Butte County, we find the same diseases present, but in this area Fusarium wilt and stem-end rot is undoubtedly the chief disease. Unless the tubers are carefully handled, considerable dry rot is also apt to develop in storage. The mosaic disease is present in this area and can be detected early in the season; the symptoms, however, are often obscured during the latter part of the season especially during periods of hot weather.

Further north, thru Dawes and Sheridan Counties, with their lower temperatures and greater rainfall, it is much easier to detect the mosaic disease, as under these conditions the symptoms are much more distinct. In a great deal of this area, scab is the chief disease, with Fusarium wilt next in importance. Blackleg also occurs in some fields but is only locally important.

GENERAL CONTROL METHODS

Most of the serious potato diseases are caused by parasitic organisms that are carried either in or on the seed tubers, and in this way they are introduced into new potato growing regions. Some of these organisms are also capable of living in the soil after they have once been introduced; others are present in practically all soils. Thus, the infection of the plant may result from several sources. Because of this it is not possible to control all the diseases by any one method. Usually more than one method is necessary in order to combat a single disease. It is obvious that such a disease as potato scab cannot be successfully controlled by seed treatments if the soil used is heavily infested. Thus, in order to produce healthy potatoes, and to obtain the greatest yields, it becomes necessary to practice several methods of control.

SEED SELECTION

The first essential step in the control of potato diseases is the selection of seed tubers. Some diseases, such as Fusarium wilt, blackleg, mosaic, and leaf-roll, are carried inside of the tubers and so are not affected by seed treatments. Such diseases can be controlled only by the selection of healthy seed.

It is not enough to select tubers free from the surface blemishes of scab and Rhizoctonia. Healthy seed tubers can be obtained only by inspecting the plant in the field, where the symptoms of these diseases carried inside of the tubers are evident. The grower should first learn the characteristic growth of a normal plant of the variety to be selected. Vigorous plants free from disease can be staked out and harvested separately. Only plants producing the greatest yield, with tubers of the proper type and free from disease, should be selected. Tubers from such plants should be carefully stored, treated, and planted on clean soil in a separate plot. This seed plot can then be used the following year as a source of seed for larger plantings and for the further selection of seed for the next year's seed plot. After a vigorous, disease-free strain of potatoes is thus established, it should be further inspected each year and the hills showing disease, weakness, off variety, or undesirability in any way should be pulled out and discarded.

The grower who raises potatoes for seed purposes must examine and rogue his entire acreage. A thoro inspection

should be made at blossoming time, when many diseases are evident and varietal mixtures are easily detected. Undesirable plants of all types should be removed. A later inspection should be made for wilt and for other diseases showing up after the first inspection. Another inspection is necessary at digging time for the detection of scab and Rhizoctonia. The seed grower will find it of great advantage to maintain a seed plot of about one-tenth of his total acreage for the production of his own seed.

The grower who raises potatoes for the table market can best obtain good seed by securing certified seed potatoes that have been inspected for disease freedom and absence of varietal mixtures as well as for general vigor and productiveness.

Seed selection has been found to be the most efficient way of controlling potato diseases. Such selected tubers not only are free from disease, but also have a high degree of vigor, thus enabling them to withstand successfully the attacks of organisms living over in the soil. Not only is disease eliminated but potatoes of great vigor, high yielding, and free from varietal mixtures are thus obtained.

CROP ROTATION

The practice of crop rotation is necessary in the control of diseases caused by organisms that live in the soil. The organisms producing scab, Rhizoctonia, and wilt are capable of living for a number of years in the absence of potato plants, some disease producing organisms being present even in virgin soils. The continuous growing of potatoes in the same soil allows these organisms to increase in such numbers that the yields not only are reduced but the potatoes are often unmarketable. Two and 3-year rotations are not sufficient to control these diseases; therefore longer rotations are necessary. Figure 1 shows the yields and relative amounts of scab produced with different rotations at the Scotts Bluff substation. It was found that the yields increased with the longer rotations from a total yield of 72.7 bushels per acre on land planted continuously with potatoes to 362.7 bushels where 6-year rotation was practiced. The percentage of culls and the amount of scab decreased as the yields increased. The 2 and 3-year rotations were very scabby, the 4-year rotations had but little scab, and the 6-year rotations were fairly free from scab. The writer has examined these plots during the last 2 seasons, and the amount of other diseases as well

as scab was much higher with the shorter rotations and accounted to a great extent for the low yields. It was also clear that the yield of potatoes was increased and the amount of scab decreased when alfalfa was grown previous to potatoes. The yield was greater when potatoes followed 3 years of alfalfa than where they followed only 2 years. The importance of such long rotations cannot be overemphasized for the control of potato diseases.

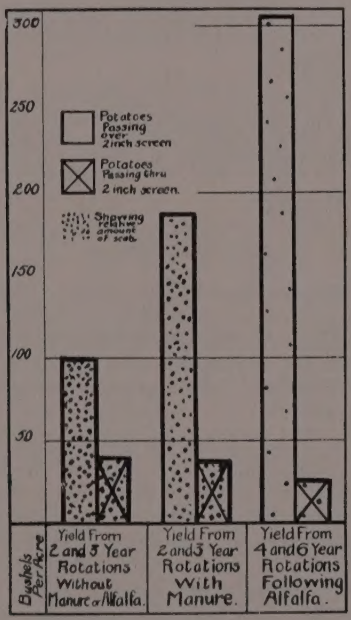
300
250
200
150
100
50
Potatoes Passing over 2 inch screen
Potatoes Passing thru 2 inch screen.
Showing relative amount of scab.
Bushels Per Acre
Yield From 2 and 3 Year Rotations Without Manure or Alfalfa.
Yield From 2 and 3 Year Rotations With Manure.
Yield From 4 and 6 Year Rotations Following Alfalfa.

FIG. 1.—Effect of short rotations including and not including manure, and long rotations including alfalfa upon yield, size and prevalence of scab on potatoes at the Scotts Bluff Experiment Farm. (From report by J. A. Holden in Nebr. Pot. Imp. Ass. Ann. Rpt. 1920.)

SOIL TREATMENT

In addition to crop rotation, it has been recommended in some states that sulphur be applied to the soil for the control of potato scab. This method of control is based upon

the fact that the organism causing potato scab grows best in an alkaline soil while a neutral or slightly acid soil prevents its growth. The addition of sulphur results in a change in the chemical nature of the soil making it unfavorable for the development of scab. Necessarily the amount of sulphur to be used would vary considerably with the soil conditions, and in many of our highly alkaline soils it would not be practicable to apply enough sulphur to change the soil reaction to a point unfavorable for the development of scab. It is probable, however, that the use of sulphur, preferably "inoculated-sulphur," on some of the soils in eastern Nebraska would aid in checking the disease.

This method of control is not generally recommended at the present time by this department because of the lack of experimental data regarding its efficiency in Nebraska. Experimental work is being planned along this line, to be conducted in the near future.

SEED TREATMENT

Diseases carried on the surface of the tuber, such as scab and Rhizoctonia, may be greatly controlled by the use of disinfection methods. These treatments will also help to control blackleg. It must be remembered that even tho the tubers look healthy the disease-producing organisms are often present on the surface.

It should always be borne in mind that seed treatment affects only those diseases that are carried over on the surface of the tuber. Furthermore, the organisms causing scab and Rhizoctonia are very often present in varying amounts in most soils, and are usually abundant in soils previously used for potatoes. Naturally, seed treatment does not prevent the reinfection of such seed from infested soil. The organisms causing both diseases are influenced greatly by temperature and moisture conditions, and scab is greatly influenced by the reaction of the soil; thus the amount of disease will vary from year to year and with different soils. Because of these facts it is impossible to determine the efficacy of seed treatment by one trial, altho growers are often prone to compare results of dissimilar tests and thus reach the wrong conclusions regarding the value of the treatment. It is only by repeated trials over a number of years on different soils that the value of such seed treatment can be accurately determined.

Experiments have proved that the corrosive sublimate treatment is the best insurance against these diseases when combined with proper seed selection and crop rotation.

The results of this treatment in Nebraska have been so uniformly successful that beginning with 1923 only fields grown from treated seed will be inspected for seed certification.

Corrosive sublimate treatment—This solution is prepared and used as follows:

Corrosive sublimate (mercuric bichloride)....4 ounces
Water .....30 gallons

Dissolve the corrosive sublimate in about one gallon of hot water and then dilute to 30 gallons. The solution is poisonous and should be kept away from children and livestock. It will also corrode metal, so that wooden or concrete vessels should be used.

Soak the uncut seed for 1½ to 2 hours. The strength of this solution decreases with each lot of seed treated. The strength can be kept constant by adding ⅜ of an ounce of corrosive sublimate after every four bushels of seed treated for 1½ hours. If a 2-hour treatment is used, add ½ ounce and for shorter treatments decrease the amount proportionately. Keep up the volume of water to the original 30 gallons. This method of keeping up the strength of the solution must be done very carefully. If the amount of water is allowed to decrease, the solution will become strong enough to cause serious injury to the eyes and sprouts.

If no additional chemical is added to the solution, increase the length of each treatment 15 minutes to make up for the loss of strength of the solution. It should be thrown away after the third or fourth treatment.

Soaking the potatoes in water for 12 to 24 hours previous to treatment helps to remove the dirt, softens up the tissue around the scab and Rhizoctonia spots, and makes the treatment more effective.

The potatoes should be treated while dormant and before cutting, about 10 days to 2 weeks before planting. They should be dried out before storing again, and care should be taken not to have them come in contact with old sacks or bins that have not been treated. Do not expect to eliminate scab and Rhizoctonia when heavily infected and rotted tubers are used. Such tubers should be discarded for seed purposes.

Better results are obtained by treating the tubers loose in barrels than by dipping in sacks. The sacks result in a more rapid weakening of the solution.

Formaldehyde treatment—Treatment with a solution of formaldehyde has often been recommended for the control of scab and Rhizoctonia. The solution is made up of 1 pint of 40 per cent formaldehyde (formalin) to 30 gallons of water and the seed treated for 2 hours. The solution does not weaken with use and so may be used repeatedly. It does not cause as much injury to sprouts as the corrosive sublimate solution. It is not, however, as effective against these diseases as corrosive sublimate.

In recent years considerable work has been done in some states with hot formaldehyde. In this treatment it is recommended that the tubers be dipped for 2 minutes in a solution of 2 pints of formaldehyde to 30 gallons of water, kept at a temperature of 118° to 122° Fahrenheit. The tubers are then piled 6 to 8 inches deep, covered with sacks for 60 minutes, and then allowed to dry. The advantage of this method lies in the considerable saving of time where large quantities of seed are to be treated. The dangers, however, are great unless considerable care is taken in regard to the temperature and length of treatment. It is necessary to use accurate thermometers because temperatures below 118° will not control the diseases while temperatures above 122° F. will injure the germination of the seed tuber. This treatment has not been tested out in Nebraska and is, therefore, not recommended as being superior to the corrosive sublimate treatment.

SPRAYING

In many of the northern states, spraying practices are necessary because of the prevalence of late blight, a disease which does not occur in Nebraska. During recent years, however, it has been found in many states that the use of Bordeaux spray, even in the absence of late blight, is profitable. This spray is made up of 4 pounds of copper sulphate (bluestone) and 4 pounds of lime, to 50 gallons of water. Arsenical poisons can be added directly to this solution. The spray not only stimulates the plants to increased growth but also materially checks the amount of tipburn on the foliage and is successful in combating hopperburn and early blight. These are the foliage diseases that are so prevalent in eastern

Nebraska. To obtain the best results, the spray should be applied at least 3 times during the season. After the foliage has been partly killed by disease it is too late to obtain good results from spraying; in fact, the use of the spray at this time would probably stimulate the plant to further growth and result in knobby tubers caused by second growth. Such a spray would probably lengthen the life of the plant in this section about 2 weeks. Whether the resulting increase in yield would make up for the later marketing of the crop in sections where early varieties are being grown is problematical. Experiments with spraying methods in eastern Nebraska are being planned to determine this point.

HANDLING, STORING, AND SHIPPING

For many years western Nebraska potatoes were discriminated against in commercial markets because of the large amount of stem rot, dry rot, and soft bacterial rots present. This trouble has been greatly reduced by more careful handling on the part of the grower and by the inspections under the State grading law.

Most of these tuber rots can be directly attributed to poor handling, storage, or shipping conditions. Very few of these diseases originate in the growing plant in the field. Such diseases as stem-end rot following wilt in the field may, however, increase in storage, chiefly due to other organisms that enter thru these diseased areas. Most of the tuber-rot organisms are present in all soils, and while they usually are not capable of penetrating thru healthy tissue, they enter the tuber thru other disease spots or thru bruises and wounds and if the tubers are kept under poor storage conditions tuber rots develop rapidly. As long as potatoes are handled with scoops and given similar rough treatment, it will be impossible to prevent the resulting rots. A great deal of injury to the tubers can be eliminated by handling the potatoes out of the field in half-sacks instead of in bulk. The potato digger is also a great cause of injury to the tubers; this can be decreased to some extent by putting more horse power on the digger and moving more dirt, thus protecting the tuber, and by the use of sloping rods on the rear of the digger instead of chains, especially in the dry land sections of western Nebraska. The storage cellar should be carefully cleaned out each season. Old rotted potatoes and culls often accumulate under the flooring and these are one source of infection for

the new tubers. Old sacks and bins that have contained rotted tubers are another source of infection. The storage cellar should be cleaned out thoroly, and if practicable, it should be disinfected by spraying the walls and floors.

Storage rots develop most rapidly when the temperature and moisture are high. Temperatures of 35° to 40° F. prevent the rapid advance of most of these organisms but do not kill them. Because of this, many infected potatoes if kept under good storage conditions will not show any great amount of rot, but when shipped out under poor conditions the tubers rot rapidly. Good ventilation, both in storage and in shipment, results in a lower relative humidity of the air and a considerable decrease in rot.

Overheating during shipping or very poor ventilation often results in the tubers arriving at their destination with a high percentage of black heart, a trouble not caused by any organism but due entirely to the conditions under which they are stored and shipped.

Careful attention to these details is absolutely necessary to prevent the considerable loss from tuber rots now so common.

POTATO DISEASES

DISEASES DUE TO PARASITIC ORGANISMS

RHIZOCTONIA

This fungous disease is common thruout Nebraska. The causal organism, *Corticium vagum* B. & C., lives over winter both on the tuber and in the soil. It is best known by its appearance on the surface of the tuber, Figure 2. The fungous growth on the surface appears as small black specks, sometimes reaching ¼ inch in size. The spots are sometimes taken for dirt, but they adhere closely to the tuber and do not wash off. They are entirely superficial on the tuber, and do not cause any great damage on table stock. Seed tubers should be free of this spot because the organism is carried over winter and introduced into the soil in this form.

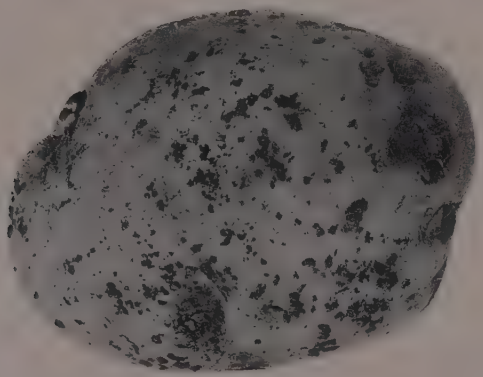

FIG. 2.—Rhizoctonia spots on surface of tuber. (Nebr. Agr. Exp. Sta.)

When such seed is planted or when the organism is abundant in the soil, the young sprouts are often attacked before they reach the surface of the ground. The growing points are killed and the stand materially reduced in this way.

Later attacks usually produce brown, dead areas on the underground stem, roots, or stolons, sometimes girdling the part attacked, Figure 3. When the main stem is entirely girdled, a large number of small tubers are sometimes formed at the surface of the ground or even in the axils of the

TABLE OF THE CHIEF

DISEASES

Common Name	Symptoms on parts chie	
	Foliage	Tubers
Rhizoctonia	Rosetting, aerial tubers	Black masses on su
Wilt	Mottling, yellowing, wilting	Stem-end rot, and brown internal
Blackleg	Wilt	Soft black rot
Scab		Round corky spot surface
Dry rot		Dry rot, with mol growth on surfa
Early blight	Small, circular spots with concentric rings	

DISEASES DUE

Mosaic and curly dwarf	Mottling and wrinkling of leaves, dwarfing of plant	Affected tubers sho symptoms
Leaf roll	Leaves rolled upward	
Net necrosis		Irregular brown n work inside
Hopperburn	Dead brown areas at tip of leaves	

DISEASES DUE TO CLIMATI

Tipburn	Dead areas at top or margin of leaf	
Black heart		Coal-black spot in center
Frost injury		Brown discoloratio thruout tuber

RASKA POTATO DISEASES

PARASITES

cted Lower stem	Method of transmission	Control
Dry brown scars girdling	Seed tubers and soil	Seed selection Seed treatment Rotation
Internal browning or brown rot; also on roots	Seed tubers and soil	Seed selection in field Rotation Good storage
Black rot, often slimy	Tubers	Seed selection Seed treatment Good storage
	Seed tubers and soil	Seed selection Seed treatment Rotation
	Thru wounds	Careful handling Good storage
	Old potato vines	Spraying Rotation

NKNOWN CAUSES

	Seed tubers and insects	Seed selection in the field
	Seed tubers and insects	Seed selection in the field
	Seed tubers	Seed selection
	Leaf hoppers	Spray

ENVIRONMENTAL CONDITIONS

		Spray
		Good storage
		Good storage Careful handling

branches, and a peculiar "rosetting" of the tops results. This disease is sometimes present in considerable amounts without materially reducing the yields; but when the infected tubers are planted the following year under conditions more favorable for the disease, the resulting disease is usually very serious.

Control—The disease is best combated by the use of clean seed, long rotations, and seed treatment with corrosive sublimate solution.

FIG. 3.—Brown dead areas characteristic of Rhizoctonia on the underground stem. (Nebr. Agr. Exp. Sta.)

FUSARIUM WILT AND STEM-END ROT

There are two different types of potato wilt present in the State, caused by two different organisms, *Fusarium oxysporum* Schlect. and *F. eumartii* Carp. They have similar life histories, however, and are controlled by the same methods, altho the symptoms are slightly different.

With the first type the early symptoms appear as a rolling and yellowing of the lower leaves, gradually affecting the entire top and causing a complete wilt. If the stem is cut across near the surface of the ground, a brown ring will be found where the fungus has invaded the water vessels of the stem. The brown discoloration sometimes extends down the inside

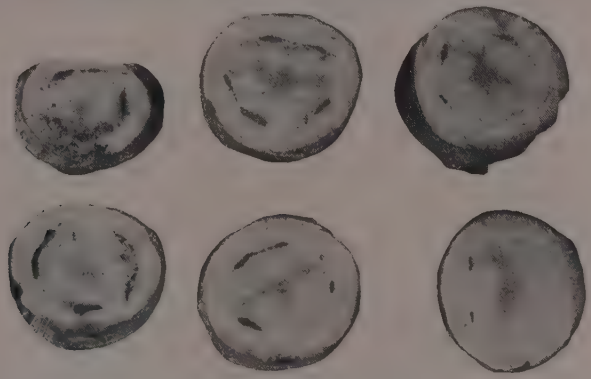

FIG. 4—Tubers cut across the stem end showing the brown ring of Fusarium wilt caused by *Fusarium oxysporum*. (Nebr. Agr. Exp. Sta.)

of the stem thru the stolons to the new tubers, there producing again a brown ring which can be observed if the stem end of the tuber is cut across. Sometimes the disease also causes brown spots on the surface of the underground stem, and on the roots. The finer rootlets are very often completely killed. The organism enters the plant either from internally infected seed-pieces or from the soil. The greater percentage of the infection comes from the soil, either by entering thru the roots or in some cases by rotting the seed-piece and advancing up the sprout. The appearance in the tuber is shown in Figure 4. This brown ring does not advance to any extent in storage and does not often produce a rotting of the seed-piece.

The second type of wilt differs from the first, both on the tops and in the tubers. The disease first appears on the foliage as small, pale green spots scattered over the surface of the lower leaves, giving them a mottled appearance. This is particularly characteristic on the Bliss Triumph variety. On the Early Ohio, the mottling is not so marked and the entire foliage rapidly turns yellow. The disease begins to show about blossoming time and reaches its most severe form one or two weeks before digging. The underground parts are attacked as in the first type of wilt, but the damage is more severe and the progress of the disease more rapid. The

FIG. 5.—Section of tuber affected with the wilt and stem-end rot disease caused by *Fusarium eumartii*. Note the rotted, sunken area at the stem end and the discolored area showing the advance of the organism thru the tuber.

new tubers often show a considerable amount of stem-end rot, even before they are mature. This rot appears always at the stem-end, as a sunken area at first very small and gradually increasing until the entire stem-end is sunken and rotten, Figure 5. This stage is favored by moist weather, when the rot develops rapidly. Under dry conditions it does not progress very far but does serve as a means of entrance for other tuber-rot organisms. The tubers may often be heavily infected in the absence of any stem-end rot, the interior showing

brown to black discolored rings. When a brown discolored ring is present with this type of wilt, it usually spreads out thru the surrounding tissue as shown in Figure 6.

The best control for these wilt diseases is the use of healthy, vigorous seed planted on clean land. Seed disinfection has no effect on the disease. Although much of the disease comes from the soil, it has been found that good healthy seed of vigorous stock shows much less infection even on heavily infested soil than does the weak, internally discolored or stem-end rot tubers. Such tubers should be discarded for seed purposes. It is not advisable to attempt to cut off the infected portions of seed tubers.

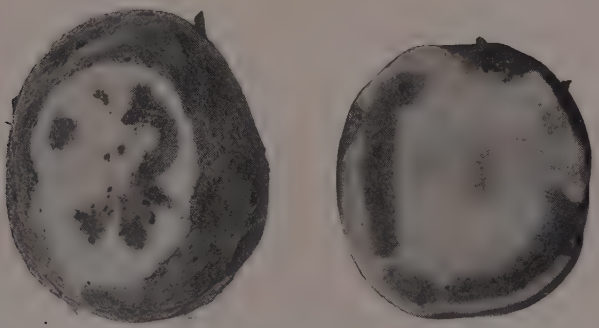

FIG. 6—Showing ring discoloration and soft rot of the adjoining tissue in tubers affected with wilt and stem-end rot caused by *Fusarium eumartii.*

Wilt is favored by high temperatures. After infection has taken place, the wilt symptoms appear more rapidly under dry conditions. However, with plenty of moisture the stem-end rot progresses more rapidly even tho the top may not be greatly wilted. The disease causes great losses to the potato crop in certain areas of the State.

There is sometimes a brown discoloration present in tubers grown on very dry soil in hot weather. This browning is not caused by a parasite and it is not transmitted thru the seed altho it is often confused with Fusarium wilt.

BLACKLEG

This disease is caused by a bacterial organism *Bacillus phytophthorus* Appel and the symptoms are described very well by the common name of blackleg. The disease starts in the seed tuber, which often completely decays. It then travels up the main stem to a height of several inches above the surface of the ground. The infected portion of the stem is usually black, and in the early stages is often soft and slimy. Later the entire plant turns yellow and wilts completely and the rotted portion of the stem may dry and shrivel. The rot may extend down the stolons to the new tubers and start a soft, slimy black rot at the stem end. These tubers may spread the disease in the bin and if used for seed will cause infection the following year.

The disease is favored by moist, cool weather. It is rare in the dry land sections of western Nebraska, but is sometimes very severe in sections where the moisture is abundant.

The organism does not live over winter in the soil but is carried over in the seed tuber. Only a small amount of the disease is controlled by seed treatment, as the organisms on the inside of the tuber are not reached. Seed treatment does effectively kill the organism on the outside of tubers that have been in contact with badly rotted potatoes. The disease can be eliminated only by careful seed selection from fields not seriously affected with the disease.

SCAB

Common scab caused by the fungous organism, *Actinomyces scabies* (Thaxter) Gussow., is familiar to all potato growers. In some sections on soils favorable for the disease it causes very severe losses. The tuber is the main part of the host attacked, altho in cases of heavy infection spots are also found upon the underground stems and stolons. The affected tubers show rough corky brown patches varying in size from very small spots to areas over half an inch in size. In some cases the greater part of the surface of the tuber may be covered with these spots. Sometimes wireworms, white grubs, and mites enter and cause a deepening of the spot, often known as deep or pitted scab. The causal organism is carried over in these diseased areas and also lives over winter in the soil. It is capable of attacking other crops, such as sugar beets and turnips. It is favored by alkaline soils and

infection is usually greatest during hot weather. Where soil moisture has been abundant and followed by a packing of the soil and poor aeration, the disease is usually prevalent.

To control this disease seed selection, seed treatment, preferably with corrosive sublimate, and long rotations are necessary. Sulphur treatments of soil may be beneficial in some cases but are not generally recommended for Nebraska.

DRY ROT

One organism, *Fusarium trichothecioides* Wollenw., causes by far the greatest per cent of the tuber rots in Nebraska. This rot is often spoken of as the powdery dry rot and is very prevalent in stored potatoes of western Nebraska. This disease normally affects only mature tubers, and while the organism is capable of infecting the growing plant, this rarely occurs. It is not able to penetrate sound, healthy tubers but gains entrance only thru wounds and deep scab spots. It

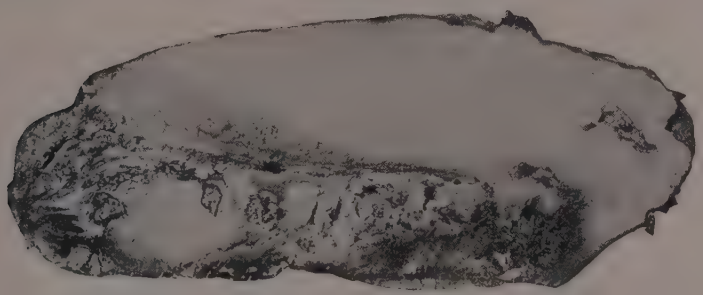

FIG. 7—Tuber badly affected with dry rot. (Nebr. Agr. Exp. Sta.)

develops in storage, where it often results in a complete dry rot of the tuber. Usually the tuber will be shrivelled and sunken, with white or pinkish tufts of the organism scattered over the surface. There are often numerous cavities in the tuber filled with white or pinkish fungous growth as shown in Figure 7. Under very moist storage conditions, the rot becomes soft. This rot develops at lower temperatures than most of the tuber rots of the potato, but its development is checked at temperatures of 34° to 40° F. altho it must be remembered that the organism is not killed and will commence further growth as soon as the temperature is raised.

The only practical method of control for this disease is the very careful handling of the tubers after digging. In most of western Nebraska, wounded or badly bruised tubers usually develop dry rot, because the organism is present in great abundance. It is only by taking the greatest precautions against wounding and by keeping the tubers in good storage that the disease can be materially checked.

OTHER TUBER ROTS

There are a large number of organisms capable of causing a rot of the potato tuber. Most of these organisms depend upon wounds for entrance to the tuber. After entering they produce a dry or a wet rot, depending chiefly upon the amount of moisture present in the air. The fungous rots are chiefly characterized by white, pink, or blue moldlike growths that break thru the skin over the sunken rotted area. The bacterial rots produce a soft, watery, bad-smelling type of rot, usually progressing more rapidly and causing a complete decay of the tuber.

All these rots are held in check by low storage temperatures. They are controlled by careful handling to avoid wounds and by eliminating all rotted or badly wounded tubers when first placed in storage. Good ventilation results in a lower moisture content of the air and decreases the amount of tuber rot. A careful inspection when the tubers are being stored would eliminate much of the trouble.

EARLY BLIGHT

This is a common disease caused by the fungus *Alternaria solani* (E. & M.) J. & G., but it is not usually serious in Nebraska. In some seasons, however, the disease causes a considerable amount of damage locally. The disease is confined to the leaves and the damage is directly proportional to the leaf area killed. The spots are usually $\frac{1}{8}$ to $\frac{1}{4}$ of an inch in diameter, circular, and are marked by concentric rings. These spots often unite and kill a greater portion of the leaf. When combined with tipburn, the foliage is often completely killed 2 weeks before the tubers are mature. The disease is not serious until late in the growing season, and is favored by high temperatures and abundant moisture. Continued drought completely checks its spread.

Control—This disease is usually not serious enough in Nebraska to warrant the expense of spraying for its control.

It is controlled by 3 or 4 sprayings with 4-4-50 Bordeaux mixture. This spray is not a cure but must be applied thruout the season in order to prevent infection from occurring.

DISEASES DUE TO UNKNOWN CAUSES

There are a number of potato diseases of which the causal agent is not known or at least not definitely proved as yet. Certain facts regarding the symptoms, methods of transmission and control of these diseases have, however, been worked out. From a practical standpoint an extensive knowledge of all these diseases is not necessary providing the symptoms are somewhat similar and the general life history of the disease and its control methods the same.

Degeneracy or "running out" of potatoes sometimes attributed to unfavorable environmental conditions or to the continued use of the same strain of seed, is in most cases probably due to one or more of these poorly understood diseases such as mosaic, curly dwarf, leaf roll, spindling sprout, net necrosis and others. They may be generally classified as degeneration diseases. The old practice of obtaining new seed stock when the old was "running out" is still the best method of overcoming this trouble, providing the seed introduced is disease free.

MOSAIC AND CURLY DWARF

This disease is common thruout the United States, and is particularly severe upon the Bliss Triumph variety. The disease in some years does not greatly reduce the yield of potatoes in western Nebraska, but when infected seed is sent south the loss is very great and becomes one of the chief limiting factors in the production of potatoes in the southern states. Because of this fact, it is of the greatest concern to the growers of seed potatoes in western Nebraska.

The disease often causes the leaves of the plant to take on a mottled appearance, as shown in Figure 8. The healthy green of the leaf is spotted with small, scattered, irregular-shaped areas of light or yellowish-green tissue, seldom greater than one-fourth of an inch in size. It is from this mottling that the disease obtains the name mosaic. Often the mottling is accompanied by a wrinkling or ruffling of the leaf surface, and sometimes this latter symptom is present in the absence of any mottling. The symptoms vary considerably

with the variety, the climatic conditions under which the plant is growing, and the severity of the disease. In western Nebraska the disease is often very hard to identify because the symptoms are often obscured by the type of growth of the potato in certain sections. In the northern counties with lower temperatures and higher moistures, the mottling of the foliage is very distinct while further south, the mosaic appearance of the leaves is almost entirely absent. It is often possible to detect the disease during the early stages of growth, while later in the season the symptoms may be obscured.

FIG. 8.—On the left, a potato leaf with the mosaic disease; on the right, a healthy leaf. (Courtesy Louisiana Agricultural Experiment Station.)

While the only visible symptoms are on the foliage, the disease is transmitted thru the tubers even tho the tubers appear perfectly healthy; thus bin inspections for this disease are worthless and the presence of the disease must be determined by field inspections. All tubers from a mosaic plant will reproduce the disease the following year.

The cause of this disease is not known. It has, however, been shown to be infectious and is transmitted in the field by

aphids or plant lice. Potato beetles and flea beetles apparently are not able to carry the disease. When the disease is carried by insects from an infected plant to a healthy plant late in the season, the symptoms sometimes do not show; nevertheless, the tubers from this plant will reproduce the disease. Attempts to transmit the disease thru the soil or by cutting knives have not been successful.

Control—In the dry land sections of western Nebraska there are few of the insects present that spread the disease. Therefore, it is possible to control the disease by careful seed selection in the field. All plants showing mosaic should be discarded, and if there is a large percentage of plants infected it is advisable to obtain new seed stock as free of the disease as is possible. The isolation of fields being used for growing seed would greatly lessen the danger of infection.

Closely associated with mosaic and sometimes considered simply as a more severe infection of the same disease is a trouble commonly known as curly dwarf. The disease is characterized by a dwarfing of the entire plant, often accompanied by a curling downward of the leaves. The plant often dies prematurely. It is much more noticeable in the fields than mosaic and causes a greater reduction in yield, the tubers from such plants being few, small, and unmarketable. The disease is transmitted in the same way as mosaic and is controlled by the same methods.

LEAF ROLL

This disease is somewhat similar to mosaic, in that it is chiefly transmitted thru the seed tubers or from plant to plant by aphids. The cause is unknown. Diseased plants have an upward rolling of the leaves giving the plants a stiff, erect appearance, Figure 9. They are often smaller than normal, and are slightly yellowish in color. The yield of such plants is greatly reduced. The tubers should be discarded for seed purposes and the plants removed from the fields.

NET NECROSIS

The tubers produced by leaf roll plants are often found to have an internal discoloration which shows as a fine, intricate, network of brownish strands scattered thruout the entire tuber.

This tuber injury should not be confused with the ring discoloration produced in Fusarium wilt or with frost necrosis.

While it has not been proved that tubers showing net necrosis will always produce leaf roll plants, it is evident that such seed is not healthy and vigorous and would probably be more liable to give rise to "spindling sprout" and to produce weak plants than would healthy seed. They should, therefore, be discarded for seed purposes.

FIG. 9.—Leaf-roll plant showing typical curling of leaf and slender erect type of growth. (Nebr. Agr. Exp. Sta.)

HOPPERBURN

This trouble combined with tipburn causes the early death of the potato foliage so common in eastern Nebraska. The potato leaf hopper sucks the juices or sap of the plants chiefly from the larger veins in the upper half of the leaf. This results in a yellowing and curling of the leaf. At the same time, the insect apparently transmits a disease which causes the death of the leaf tissue. The disease appears on the leaf as a slight yellowing, gradually turning brown, and later the leaf curls upward and dies. The disease spreads toward the midrib and base of the leaf. It is usually very serious during

periods of hot, dry weather, and is checked by moist, cool conditions.

Control—The most effective method of control for this disease is a spray of Bordeaux 4-4-50. The spray must be applied thoroly and especially on the underside of the leaves. The spray should be applied about 3 times, depending upon weather conditions and the number of insects present.

DISEASES DUE TO CLIMATIC OR ENVIRONMENTAL CONDITIONS

TIPBURN

This trouble is often associated and confused with hopperburn. The effects on the foliage are somewhat similar and the control measures are the same. Tipburn is due to excessive heat and sunshine during the latter half of the growing season. It shows first as a dying at the extreme tip of the leaves and around the margins and gradually progresses down the leaf tissue until in severe cases the whole leaf dies. The affected tissue turns brown or black, dries up, and shrivels, Figure 10. The disease advances most rapidly on hot, bright days, and is checked by cool or cloudy weather. A cool, cloudy period following even a severe attack of tipburn often results in a renewed growth of the tops, the new leaves usually being small and curled. Such renewed growth after the development of the tubers has been checked often results in misshapen, malformed, and unmarketable tubers. In eastern Nebraska this trouble results in the death of most of the foliage a considerable time before maturity. Early varieties are affected more seriously than late ones.

The disease may be largely prevented by the application of a spray of Bordeaux mixture.

BLACK HEART

Tubers affected with this disease when cut open show a coal black, slightly moist, dead, irregular-shaped area in the center of the tuber. Sometimes the center is grayish in color, surrounded by a black ring. In badly affected tubers, there is often a cavity formed in the center surrounded by this blackened dead tissue. The trouble may spread outward until the surface is reached, when a soft rot often develops. The disease is not usually observable from the outside and can only be determined by cutting the tuber open.

Black heart results when tubers are overheated or smothered. This usually occurs in shipping, when potatoes are not given sufficient ventilation and when the temperature becomes too high. It can be entirely eliminated by careful attention to ventilation and heat.

FIG. 10.—On left, leaves from vine affected with tipburn; leaves on right, from plant protected by shading. Both plants were from the same mother tuber.

HOLLOW HEART

Large tubers are often found to contain a large cavity in the center. This is surrounded by healthy tissue altho the walls of the cavity may take on a brown, corky appearance. This abnormal condition is not caused by a parasite but it is the result of too rapid a growth of the tuber and can often be prevented under irrigation by applying less water and planting closer.

INTERNAL BROWN SPOT

When tubers affected with this disease are cut open they will show large irregular-shaped, light brown areas scattered thruout the tuber, Figure 11. No organisms are present, and the malady is not transmitted by the tubers. This trouble is probably the result of some previous unfavorable condition during the growth of the tuber. It is often confused with certain types of frost injury. Tubers showing this disease should not be used for seed purposes.

FIG. 11.—Tuber showing internal brown spot. (Nebr. Agr. Exp. Sta.)

FROST NECROSIS OR FREEZING INJURY

There is always some damage to tubers caused by heavy frosts either before or during the digging of the crop. Similar losses occur during the storing season and particularly in transportation, either in the cars, or often during a long haul in wagons to the shipping point. When tubers are frozen solid, there is a complete collapse after thawing, they become soft and wet, and rots may develop rapidly. These tubers are easily detected and should be sorted out.

However, in cases where the chilling has not been so severe, the potatoes may not show any external symptoms, or only slightly darkened areas on the surface and a more rapid shrinking. When cut open, these tubers show variable evidences of frost or chilling injury. The stem end of the tuber is more sensitive to chilling than the bud end, and the vascular tissue is also very sensitive. Experiments conducted by the Wisconsin Experiment Station have shown that the internal

discolorations appear as (1) a ring discoloration, especially severe at the stem end and often confused with Fusarium wilt; (2) a network of discolored strands scattered thruout the tuber (see Figure 12); or (3) as irregular-shaped blotches distributed thru the tuber. These discolorations develop quickly after freezing. Such injury will develop in tubers submitted to a temperature of about 14° for 1 hour, to 23°

FIG. 12.—Tuber showing frost injury produced experimentally.

for 2 hours, or 27° F. or slightly lower for several hours. Different tubers will show varying degrees of injury under the same conditions. Sprouts are more resistant to freezing than tubers, but tubers showing frost injury often fail to develop plants and it is not advisable to use them for seed purposes.

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